

1                    WHAT IS CLAIMED IS:

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- 3    1.    A method of using a position-velocity table to control a dynamic system, the
- 4           method comprising the steps of:
- 5                     generating a position variable for the system;
- 6                     determining a velocity command for the system using the position-
- 7           velocity table, the determining step determining the velocity command
- 8           based on the position variable;
- 9                     shaping the velocity command in order to generate a shaped
- 10          velocity command; and
- 11          controlling the system based on the shaped velocity command.
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- 13    2.    A method according to Claim 1, wherein the method controls a component of the
- 14          dynamic system, the component comprising a head of a data storage device; and
- 15                     wherein the controlling step controls the head to move among
- 16          various tracks of a data storage medium in the data storage device.
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- 18    3.    A method according to Claim 2, wherein the generating step comprises comparing
- 19          a preset position of the component to a measured position of the component in
- 20          order to determine the position variable; and
- 21                     wherein the method further comprises the step of performing
- 22          inverse shaping on the measured position prior to comparing the measured
- 23          position to the preset position.
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- 25    4.    A method according to Claim 3, wherein the shaping step and the inverse shaping
- 26          step reduce unwanted vibrations resulting from movement of the component.
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- 28    5.    A method according to Claim 3, wherein the measured position of the component
- 29          is determined after the controlling step controls the component; and

1                    wherein the measured position of the component is fed back to the  
2                    determining step following the controlling step.

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4    6.    A method of generating a trajectory for inclusion in a position-velocity table  
5           which is used to control a dynamic system, the method comprising the steps of:

6                    generating a trajectory for the dynamic system, the trajectory  
7                    defining system velocity in terms of system position and one or more  
8                    additional variables;

9                    storing the trajectory in a position-velocity table having N ( $N > 2$ )  
10                  dimensions; and

11                  controlling the dynamic system in accordance with the trajectory  
12                  stored in the position-velocity table.

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14    7.    A method according to Claim 6, wherein the method controls a component of the  
15           dynamic system, the component comprising a head of a data storage device; and

16                    wherein the controlling step controls the head to move among  
17                    various tracks of a data storage medium in the data storage device.

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19    8.    A method according to Claim 7, wherein one of the variables comprises a desired  
20           movement distance of the component.

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22    9.    A method according to Claim 7, wherein the trajectory is generated in real-time  
23           based on a partial fraction expansion that defines behavior of the dynamic system.

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25    10.   A method of controlling a dynamic system in accordance with a variation in a  
26           system variable, the method comprising the steps of:

27                    generating a plurality of trajectories defining system velocity in  
28                    terms of system position, the plurality of trajectories being generated in  
29                    accordance with at least one system variable;

1 storing the plurality of trajectories in a single position-velocity  
2 table;  
3 detecting a value of the at least one system variable; and  
4 controlling the dynamic system in accordance with both the  
5 detected value of the system variable and the trajectories stored in the  
6 position-velocity table.  
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- 8 11. A method according to Claim 10, wherein the position-velocity table comprises a  
9 series of trajectories corresponding to various component movement distances;  
10 and

11 wherein the controlling step comprises selecting one of the  
12 trajectories from the position-velocity table based on the detected value of  
13 the system variable and controlling a component of the dynamic system in  
14 accordance with the selected trajectory.  
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- 16 12. A method according to Claim 10, wherein the controlling step comprises  
17 generating a function based on the plurality of trajectories and the system  
18 variable, determining a single trajectory for the component based on the function,  
19 and controlling a component of the dynamic system based on the single trajectory.  
20

- 21 13. A method according to Claim 10, wherein the generating step comprises the steps  
22 of:

23 estimating system parameters, the system parameters relating to  
24 movement of a component of the dynamic system;

25 determining whether the system parameters have varied from  
26 predetermined system parameters;

27 modifying the trajectories based on determined system parameter  
28 variations; and

29 storing the modified trajectories in the position-velocity table.  
30

- 1 14. A method of generating a trajectory for inclusion in a position-velocity table  
2 which is used in controlling a dynamic system, the method comprising the steps  
3 of:  
4 generating a trajectory for use in the dynamic system;  
5 storing the trajectory in the position-velocity table; and  
6 controlling the dynamic system in accordance with the trajectory  
7 stored in the position-velocity table;  
8 wherein the generating step generates the trajectory in accordance  
9 with a technique for reducing unwanted vibrations in the dynamic system.  
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- 11 15. A method according to Claim 14, wherein the method controls a component of the  
12 dynamic system, the component comprising a head of a data storage device; and  
13 wherein the controlling step controls the head to move among  
14 various tracks of a data storage medium in the data storage device.  
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- 16 16. A method according to Claim 15, wherein the technique for reducing unwanted  
17 vibrations of the component comprises generating the trajectory by taking into  
18 account both a system vibration limiting constraint and a system sensitivity  
19 constraint.  
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- 21 17. A method according to Claim 16, wherein the system vibration limiting and  
22 sensitivity constraints reduce vibration during movement of the component by  
23 less than 100%.  
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- 25 18. A method according to Claim 15, wherein the technique for reducing unwanted  
26 vibrations of the component comprises generating the trajectory by taking into  
27 account one or more constraints which are a function of a movement distance of  
28 the component.  
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- 1 19. A method according to Claim 15, wherein the technique for reducing unwanted  
2 vibrations of the component comprises generating the trajectory by taking into  
3 account a system vibration limiting constraint only.  
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- 5 20. A method according to Claim 15, wherein the technique for reducing unwanted  
6 vibrations of the component comprises generating the trajectory based on an input  
7 which has been shaped in accordance with a predetermined shaping function.  
8
- 9 21. A method according to Claim 20, wherein the input includes both transient  
10 portions and a steady state portion; and  
11 wherein only the transient portions of the input have been shaped  
12 in accordance with the predetermined shaping function.  
13
- 14 22. A method according to Claim 15, wherein the technique for reducing unwanted  
15 vibrations of the component comprises generating the trajectory by filtering a  
16 predetermined trajectory using filters having zeros which are substantially near  
17 poles of the system.  
18
- 19 23. A method according to Claim 15, wherein the technique for reducing unwanted  
20 vibrations of the component comprises generating the trajectory by taking into  
21 account at least one of constraints relating to system thermal limits, system  
22 current limits, and system duty cycle.  
23
- 24 24. A method according to Claim 15, wherein the technique for reducing unwanted  
25 movement of the component comprises the steps of:  
26 determining whether a trajectory excites greater than a  
27 predetermined level of vibrations in the system; and  
28 applying input shaping to the trajectory in a case that the trajectory  
29 excites greater than the predetermined level of vibrations.  
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- 1 25. A method according to Claim 15, wherein the technique for reducing unwanted  
2 vibrations of the component comprises generating the trajectory based on a  
3 Posicast input.  
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- 5 26. A method according to Claim 15, wherein the technique for reducing unwanted  
6 vibrations of the component comprises generating the trajectory based on a  
7 symmetric input.  
8
- 9 27. A method according to Claim 15, wherein the technique for reducing unwanted  
10 vibrations of the component comprises generating the trajectory based on a  
11 symmetric constraint that varies as a function of at least one of time and  
12 component position.  
13
- 14 28. A method according to Claim 15, wherein the technique for reducing unwanted  
15 vibrations of the component comprises generating a trajectory in accordance with  
16 a voltage which has been controlled by controlling current.  
17
- 18 29. A method according to any one of Claims 14 to 28, wherein the generating step  
19 comprises:  
20 identifying system parameters in real-time; and  
21 modifying the trajectory in real-time in accordance with the system  
22 parameters identified in the identifying step.  
23
- 24 30. A data storage device which uses a position-velocity table to control movement of  
25 a component of the data storage device, the data storage device comprising:  
26 a memory which stores the position-velocity table and computer-  
27 executable process steps; and  
28 a processor which executes the process steps stored in the memory  
29 so as (i) to generate a position variable for the component, (ii) to  
30 determine a velocity command for the component using the position-

1 velocity table, the processor determining the velocity command based on  
2 the position variable, (iii) to shape the velocity command in order to  
3 generate a shaped velocity command, and (iv) to control the component to  
4 move based on the shaped velocity command.

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6 31. A data storage device according to Claim 30, wherein the component comprises a  
7 head of the data storage device; and

8 wherein the processor controls the head to move among various  
9 tracks of a data recording medium in the data storage device.

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11 32. A data storage device according to Claim 30, wherein, to generate a position  
12 variable for the component, the processor compares a preset position of the  
13 component to a measured position of the component; and

14 wherein the processor further performs inverse shaping on the  
15 measured position prior to comparing the measured position to the preset  
16 position.

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18 33. A data storage device according to Claim 32, wherein the shaping and inverse  
19 shaping performed by the processor reduce unwanted vibrations resulting from  
20 movement of the component.

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22 34. A data storage device according to Claim 32, wherein the processor determines  
23 the measured position of the component after controlling the component; and

24 wherein the processor uses a previously-measured position of the  
25 component to determine the position variable.

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27 35. An apparatus which generates a trajectory for inclusion in a position-velocity  
28 table that is used in to control a dynamic system, the apparatus comprising:

29 a memory which stores computer-executable process steps and a  
30 position-velocity table having  $N$  ( $N > 2$ ) dimensions; and

1 a processor which executes the process steps stored in the memory  
2 so as (i) to generate a trajectory for the system, the trajectory defining  
3 system velocity in terms of system position and one or more additional  
4 variables, (ii) to store the trajectory in the position-velocity table, and (iii)  
5 to control the system in accordance with the trajectory stored in the  
6 position-velocity table.

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8 36. An apparatus according to Claim 35, wherein the apparatus controls a component  
9 of the dynamic system, the component comprising a head of a data storage device;  
10 and

11 wherein the processor controls the head to move among various  
12 tracks of a data storage medium in the data storage device.

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14 37. An apparatus according to Claim 36, wherein one of the variables comprises a  
15 desired movement distance of the component.

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17 38. An apparatus according to Claim 36, wherein the processor generates the  
18 trajectory in real-time based on a partial fraction expansion that defines behavior  
19 of the dynamic system.

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21 39. An apparatus which controls a dynamic system in accordance with a variation in a  
22 system variable, the apparatus comprising:

23 a memory which stores a position-velocity table and computer-  
24 executable process steps; and

25 a processor which executes the process steps stored in the memory  
26 so as (i) generate a plurality of trajectories defining velocity in terms of  
27 position, the plurality of trajectories being generated in accordance with at  
28 least one system variable, (ii) to store the plurality of trajectories in the  
29 position-velocity table, (iii) to detect a value of the at least one system  
30 variable, and (iv) to control the dynamic system in accordance with both

1 the detected value of the system variable and the trajectories stored in the  
2 position-velocity table.

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4 40. An apparatus according to Claim 39, wherein the position-velocity table  
5 comprises a series of trajectories corresponding to various component movement  
6 distances; and

7 wherein the processor controls a component of the dynamic system  
8 by selecting one of the trajectories from the position-velocity table based  
9 on the detected value of the system variable and by controlling the  
10 component in accordance with the selected trajectory.

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12 41. An apparatus according to Claim 39, wherein the processor controls a component  
13 of the dynamic system by generating a function based on the plurality of  
14 trajectories and the system variable, by determining a single trajectory for the  
15 component based on the function, and by controlling the component based on the  
16 single trajectory.

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18 42. An apparatus according to Claim 39, wherein the processor generates the plurality  
19 of trajectories by (i) estimating system parameters, the system parameters relating  
20 to movement of a component of the dynamic system, (ii) determining whether the  
21 system parameters have varied from predetermined system parameters, (iii)  
22 modifying the trajectories based on determined system parameter variations, and  
23 (iv) storing the modified trajectories in the position-velocity table.

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25 43. An apparatus for generating a trajectory for inclusion in a position-velocity table  
26 which is used in controlling a dynamic system, the apparatus comprising:

27 a memory which stores the position-velocity table and computer-  
28 executable process steps; and

29 a processor which executes the process steps stored in the memory  
30 so as (i) to generate a trajectory for the system, (ii) to store the trajectory

1 in the position-velocity table, and (iii) to control the system in accordance  
2 with the trajectory stored in the position-velocity table;  
3 wherein the processor generates the trajectory in accordance with a  
4 technique for reducing unwanted vibrations in the system.  
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6 44. An apparatus according to Claim 43, wherein the apparatus controls a component  
7 of the dynamic system, the component comprising a head of a data storage device;  
8 and

9 wherein the processor controls the head to move to among various  
10 tracks of a magnetic disk in the disk drive.  
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12 45. An apparatus according to Claim 44, wherein the technique for reducing  
13 unwanted vibrations of the component comprises generating the trajectory by  
14 taking into account both a system vibration limiting constraint and a system  
15 sensitivity constraint.  
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17 46. An apparatus according to Claim 45, wherein the system vibration limiting and  
18 sensitivity constraints reduce vibration during movement of the component by  
19 less than 100%.  
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21 47. An apparatus according to Claim 44, wherein the technique for reducing  
22 unwanted vibrations of the component comprises generating the trajectory by  
23 taking into account one or more constraints which are a function of a movement  
24 distance of the component.  
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26 48. An apparatus according to Claim 45, wherein the technique for reducing  
27 unwanted vibrations of the component comprises generating the trajectory by  
28 taking into account a system vibration limiting constraint only.  
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- 1 49. An apparatus according to Claim 44, wherein the technique for reducing  
2 unwanted vibrations of the component comprises generating the trajectory based  
3 on an input which has been shaped in accordance with a predetermined shaping  
4 function.  
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- 6 50. An apparatus according to Claim 49, wherein the input includes both transient  
7 portions and a steady state portion; and  
8 wherein only the transient portions of the input have been shaped  
9 in accordance with the predetermined shaping function.  
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- 11 51. An apparatus according to Claim 44, wherein the technique for reducing  
12 unwanted vibrations of the component comprises generating the trajectory by  
13 filtering a predetermined trajectory using filters having zeros which are  
14 substantially near poles of the system.  
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- 16 52. An apparatus according to Claim 44, wherein the technique for reducing  
17 unwanted vibrations of the component comprises generating the trajectory by  
18 taking into account at least one of constraints relating to system thermal limits,  
19 system current limits, and system duty cycle.  
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- 21 53. An apparatus according to Claim 44, wherein the technique for reducing  
22 unwanted movement of the component comprises the steps of:  
23 determining whether a trajectory excites greater than a  
24 predetermined level of vibrations in the system; and  
25 applying input shaping to the trajectory only in a case that the  
26 trajectory excites greater than the predetermined level of vibrations.  
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- 28 54. An apparatus according to Claim 44, wherein the technique for reducing  
29 unwanted vibrations of the component comprises generating the trajectory based  
30 on a Posicast input.

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55. An apparatus according to Claim 44, wherein the technique for reducing unwanted vibrations of the component comprises generating the trajectory based on a symmetric input.
56. An apparatus according to Claim 44, wherein the technique for reducing unwanted vibrations of the component comprises generating the trajectory based on a symmetric constraint that varies as a function of at least one of time and component position.
57. An apparatus according to Claim 44, wherein the technique for reducing unwanted vibrations of the component comprises generating a trajectory in accordance with a voltage which has been controlled by controlling current.
58. An apparatus according to any one of Claims 43 to 57, wherein the processor generates the trajectory by (i) identifying system parameters in real-time, and (ii) modifying the trajectory in real-time in accordance with the system parameters identified by the processor.
59. A method of generating a position-velocity table for a dynamic system, the method comprising the steps of:
  - modeling the dynamic system in terms of partial fraction expansion equations;
  - integrating the partial fraction expansion equations forward in time so as to generate a trajectory for the dynamic system; and
  - storing the trajectory for the system in the position-velocity table.
60. A method according to Claim 59, wherein the partial fraction expansion equations which model the dynamic system comprise:

$$Finalpos = \sum_{i=1}^N V_i A \Delta t$$

$$0 = \sum_{i=1}^N V_i \frac{Ab}{b-a} (e^{-a(T_{end}-T_i+\Delta t)} - e^{-a(T_{end}-T_i)})$$

$$0 = \sum_{i=1}^N V_i \frac{Aa}{a-b} (e^{-b(T_{end}-T_i+\Delta t)} - e^{-b(T_{end}-T_i)}),$$

where Finalpos is the final position of a component of the dynamic system,  $T_{end}$  corresponds to a time at which Finalpos is reached, A, a and b are based on the system parameters,  $V_i$  are inputs to the system,  $T_i$  are the times at which  $V_i$  are input, and  $\Delta t$  is a time interval at which  $V_i$  are input.

61. An apparatus according to Claim 43, wherein the position-velocity table comprises a non-dimensional position velocity table.